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Stratigraphy, Stucture, and Metamorphism: Deep River Area, Connecticut

L.W., Lundgren

Stratigraphy, structure, and metamorphism

Deep River area, Connecticut

Commentary prepared by L.W.
Lundgren, University of Rochester

for

TRIP D

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Introduction

The Deep River area lies on the southern end of a chain of gneiss domes that extends northward through Connecticut and Massachusetts into Vermont and New Hampshire. The domes in New Hampshire and Vermont have been given the greatest amount of study to date (see Billings, 1956 and references cited there; Thompson and Rosenfeld, 1951). The Deep River area and the nearby Middle Haddam area provide excellent samples of the kind of relationships seen in and around gneiss domes in eastern Connecticut and some interesting comparisons with the domes further north.

The following commentary is abstracted from a Yale thesis (Lundgren, 1957) and incorporates modifications in stratigraphic nomenclature made as a result of work done since 1956. The figures have been redrafted from similar figures used in the thesis. The mapping of the Deep River and Essex quadrangles was done with the generous support of the Connecticut Geological and Natural History Survey under the directorship of John Lucke. The metamorphic problems are now being studied under a grant from the Geological Society of America (Grant GSA 799-8). Formal proposals for the stratigraphic nomenclature used here will be presented in a paper now in preparation and in quadrangle reports of the Connecticut Survey, also in preparation.

The continuing work of John Rosenfeld and Gordon Eaton in the Middle Haddam area, and of George Snyder and Richard Goldsmith of the U.S. Geological Survey in the quadrangles east and northeast of the Hamburg quadrangle has served as a basis for continuous stimulating discussion with these people, all of whom have been extremely helpful. In addition, the commentary of and discussions with John Rodgers and Matt Walton of Yale have helped me to place the Deep River area in perspective with respect to the regional setting and to other similar areas.

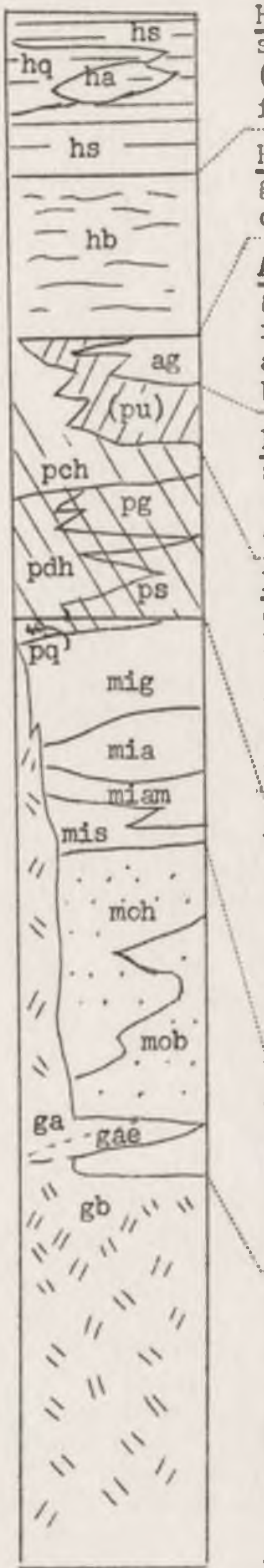
Structural setting

Three domes (Killingworth, Selden Neck, and Clinton) of quartzo-feldspathic gneiss dominate the structure of the area and its immediate surroundings (Fig. 1 and 3). Each is a domal mass of heterogeneous plagioclase gneisses; the Selden Neck and Clinton domes have cores of pink, microcline-bearing biotite granite gneiss.

The domes are separated from one another by a narrow belt of tightly folded stratified rocks that lie along a sinuous isoclinal syncline, the Chester syncline. The Chester syncline opens out to the northeast and east into a broad structural basin, the Mt. Parnassus basin. This basin and the Chester syncline might be regarded as the southern termination of the Merrimack synclinorium in New Hampshire and Massachusetts.

The southern margin of the Mt. Parnassus basin is marked by a mile-wide zone of cataclastic and mylonitic gneisses and schists marking the trace of a major thrust fault, the Honey Hill fault, which extends east of the area for twenty miles or more (Lundgren, Snyder, and Goldsmith, 1958). This fault separates the dome sequence from the synclinal sequence and is parallel with bedding and foliation in these rocks on both sides of the fault. Thus it is essentially a bedding-plane fault in the Deep River area. The fault retains its bedding-plane character even where the contact between the two sequences is folded and overturned along the east limb of the Chester syncline. The fault does not cut the Chester syncline; instead it bends at Chester (Fig. 2 and 3) to become parallel with the overturned limb of the syncline as indicated by the presence of laminar cataclastic gneisses along this limb immediately south of Chester. The displacement along the fault is negligible in the area around Chester and increases to the east.

INTERPRETATIVE COLUMNAR SECTION



Hopyard fm.- Gray Bi-Ms-Q-Pl-Gt schist with sillimanitic and rusty sulfide-bearing facies in upper part (hs). Garnetiferous Bi-Q schist (hq) and calcareous amphibolite (ha) common in upper part of Hopyard fm.

Hebron fm.- Thin-bedded Bi-Pl-Q schist and calc-silicate (Di-Act-Pl) granofels (hb). Along Honey Hill fault these rocks are mylonitic and commonly contain augen of plagioclase and microcline.

Augen gneiss along Honey Hill fault.- Cataclastic and mylonitic gneisses consisting of pink Mi (Or)-Pl-Q-Ms-Bi-Gt granite gneiss intercalated with dark-gray Pl-Q-Bi-Hbld gneiss containing abundant augen of plagioclase and orthoclase. Probably a mixture of Canterbury and Putnam gneisses.

Putnam fm.(?).- Dark-gray Bi-Pl-Q-Ms-(Gt) schist with interbedded sillimanitic quartzite, hornblende gneiss, and rusty binary schist (pu ?). Along Honey Hill fault these rocks are mylonitic and commonly contain augen of plagioclase and quartz.

Pequot Swamp fm.- Heterogeneous unit consisting of conglomeratic quartzite (pq), laminar Di-Hbld amphibolite with interbedded Bi-Q-Pl-Gt schist (pdh), Bi-Ms-Pl-Q-Gt-(Sill) and Bi-Pl-Q-Or-Sill-Gt schists (ps) with interbedded pink spessartite-quartz granulite. Uppermost schist containing abundant pegmatite laminae is the Cremation Hill schist member (pch). Garnetiferous Pl-Q-Mi-Bi gneiss with interbedded amphibolite (pgn).

Middletown fm.- Heterogeneous unit characterized by widespread occurrence of anthophyllite and cummingtonite. Consists primarily of anthophyllitic Pl-Q-Bi-(Hbld) gneiss with abundant amphibolite layers (mig), and rusty Pl-Q-Bi gneiss containing abundant anthophyllite, garnet, and quartz-tourmaline pods (mia). Also present are thin layers of garnetiferous binary schist and rusty binary quartzite (mis), diopsidic marble and amphibolite (miam), and quartz-rich gneisses containing nodular masses of quartz and sillimanite.

Monson gneiss.- Gray Pl-Q-Bi-Mt and Pl-Q-Hbld-Mt gneisses in which plagioclase is generally the only feldspar. Hornblendic gneisses (moh) more abundant in upper part, and biotitic gneisses (mob) more abundant in the lower part of the Monson. Monson gneiss adjacent to the abundant layers of alaskitic granite around the Selden Neck dome contains some microcline. Amphibolite layers common throughout.

Microcline-bearing granitic gneisses.- Pink to light-gray microcline-bearing gneisses in which the foliation is marked by parallel orientation of platey quartz and feldspar as well as by the parallel orientation of biotite, magnetite, and hornblende. Alaskitic granite gneiss (ga): Medium to fine-grained leucocratic gneiss in which magnetite is the principal mafic mineral. Total mafic mineral content less than 2%. Aegerine-augite granite gneiss (gae): Weakly gneissic aegerine-augite and riebeckite-bearing alkalic granite. Biotite granite gneiss (gb): Heterogeneous medium-grained pink granite gneiss in which microcline generally less abundant than plagioclase. Biotite is the principal accessory; hornblende is locally abundant, particularly near amphibolite layers.

Sequence, age, and correlation of the rocks in the Deep River area

The inferred stratigraphic sequence in the Deep River area is illustrated in the columnar section on the facing page. This sequence may be conveniently divided into two parts, a domal and a synclinal sequence so named on the basis of their respective structural positions.

The domal sequence (Middletown + Monson + microcline granites) is a complex of weakly foliated to sharply layered quartzo-feldspathic gneisses and relatively minor amounts of mica- and amphibole-rich schists and gneisses. It presumably includes metamorphosed sedimentary, volcanic, and intrusive rocks. Most of the rocks in this sequence map as if they were true stratigraphic units, and, on a large scale, they behave as a basement complex on which the synclinal sequence lies.

The synclinal sequence comprises mica-, calc-silicate-, and amphibole-rich schists and gneisses. The upper part of this sequence consists of metasedimentary rocks that display marked lateral uniformity; the Hebron can be followed without a break from the northern part of the Mt. Parnassus basin into and along the tortuous axis of the Chester syncline. This part of the sequence is only locally in contact with the dome sequence; it may be described as the mantle (in the sense in which this word has been used by Eskola,(1949), as it effectively mantles or is draped around the domes and is not cut by rocks belonging to the dome sequence. This may indicate that the mantle lies unconformably on the dome sequence.

The Pequot Swamp formation and the Putnam formation occupy a somewhat ambiguous position in this scheme. They too may lie unconformably on the dome sequence. (Note that the Honey Hill fault is localized along the contact between the Putnam and the Monson.)

The inferred sequence in the Deep River area is similar to the sequence around most of the gneiss domes from Long Island Sound to New Hampshire. One possible gross correlation with the well known New Hampshire section (by way of Massachusetts) is as follows.

(Hebron fm. + Hopyard fm.) = (Fitch + Littleton fms.) = Siluro-Devonian

(Middletown + Pequot Swamp fms.) = (Ammonoosuc + Partridge fms.) = Ordovician

(Monson gn. + biotite granite gn.) = (Oliverian magma series)

Monson = Ordovician or older; biotite granite gneiss = pre-Silurian.

However, we (Snyder, Rosenfeld, Eaton, Lundgren) have not yet been successful in correlating the rocks east of the Monson with those west of the Monson (see Fig. 1), so that any comparison of the Deep River section with the New Hampshire section is speculative.

As is well known, there are still problems involved in correlating the western New Hampshire section with the section in eastern New Hampshire and Massachusetts (see Billings, 1956, p. 99-105) across the broad expanse of the Merrimack synclinorium. This problem becomes acute in southern Connecticut where the Merrimack synclinorium apparently dwindles into the quantitatively insignificant Chester syncline. The Hebron and Hopyard could be equivalent to the Carboniferous (?) rocks on the east side of the Merrimack synclinorium in Massachusetts, or to the Silurian (?) Merrimack group in southeastern New Hampshire. Similarly, they might be equivalent to the rocks on the west side of the synclinorium in central Massachusetts that Hadley (1949) has equated with the Siluro-Devonian section of Western New Hampshire. However, Rosenfeld and Eaton have carried the New Hampshire section down to the Middle Haddam quadrangle (Fig. 1), and they do not find equivalents of the Hebron and Hopyard there, just as I find no equivalent of the Great Hill (= Clough) quartzite associated with the Hebron and Hopyard. If the Hebron is Silurian or younger, then the apparent lack of correlation with the Middle Haddam section may be a consequence of major sedimentary facies changes from west to east combined with the presence of north-south isoclinal folds. On the other hand, the rocks east of the Monson may not be equivalent to the Great Hill section but may be younger or older. From this it is clear that we simply do not know the age and correlation of these rocks with any exactness, and, when the correlations have been made it will still be necessary to have more data on the enigmatic Worcester phyllite and associated rocks than is yet available.

The plagioclase gneisses (Monson gneiss) form the base of the local sequence and probably are Cambrian or Ordovician equivalents of similar dome rocks to the north. The overlying Pequot Swamp formation may be equivalent to the Collins Hill formation in the Middle Haddam area and quite possibly is Ordovician. The granite gneisses are intrusive in part into the plagioclase gneisses; they are restricted to a position below the Pequot Swamp formation and are considered to be older than this and the overlying units. All the rocks are more than 260 million years old on the basis of radioactive age determinations on minerals from pegmatites in the Middle Haddam and Glastonbury quadrangles (Rodgers, 1952, p. 413-415).

Origin of the rocks in the Deep River area

The nature of the parent rocks from which the Deep River rocks were formed has been obscured by the effects of intense metamorphism and deformation, and the deeper we go in the section, the more numerous are the origins that may be attributed to these rocks. The principal guides to satisfactory interpretation are a) correlation with less-metamorphosed equivalents, b) the composition, internal structure, and associations of each unit, and c) analogies with less metamorphosed sequences seen in the axial region of geosynclines (marked by the familiar chain of alpine ultramafic rocks).

The Hopyard formation represents the metamorphic equivalent of a sequence of shale with interbedded siltstone and highly impure calcareous sedimentary rocks. The underlying Hebron formation probably originated from the metamorphism of a sequence of well bedded fine-grained sandstones and siltstone with interlayered calcareous and dolomitic siltstones. This interpretation is based on the chemical and mineralogic composition of these units and on correlation with less metamorphosed rocks to the north.

The Pequot Swamp formation seems to be the metamorphic equivalent of the varied sequences of banded tuffs, flows, agglomerates, bedded manganiferous cherts, and clastic sediments commonly deposited in the middle stages of geosynclinal sedimentation. The Baie Verte and Cape St. John groups in the Ordovician of northern Newfoundland (Baird, 1951) and the middle part of the Franciscan-Knoxville group in California (Taliaferro, 1943, p. 144-153) are examples of such sequences, as parts of the Ammonoosuc volcanics (Billings, 1937, p. 475-480) in New Hampshire may also be. Such an origin is suggested by the great variety of rock types, the rapid changes along strike, and the widespread occurrence of beautifully banded amphibolite (= banded pyroclastic rocks) associated with well bedded spessartite-quartz granulite (= bedded manganiferous chert).

The dome complex consists of rocks that have generally been regarded as magmatic intrusives (see e.g. Mikami and Digman, 1957); the same is true of their probable equivalents to the north (e.g. the Oliverian magma series). The composition, associations, and widespread occurrence of rocks similar to the Monson in a similar stratigraphic position in other domes suggests that the Monson is a product of metamorphism of a geosynclinal suite of quartz keratophyre and andesitic volcanics and associated sedimentary rocks. The Middletown formation probably evolved from a similar sequence in which basaltic volcanics and associated chert and limestone were more abundant.

The microcline-bearing granite gneisses are heterogeneous; modal analyses indicate a continuous gradation to adjacent plagioclase gneiss. The granite gneisses were metamorphosed concurrently with the other rocks and thus are of indeterminate origin. They probably represent metamorphosed intrusives surrounded by granitized plagioclase gneiss. Modal analyses of alaskitic and aegerine-augite-bearing granite, which occurs in layers peripheral to the core of the Selden Neck dome, illustrate the uniform composition of these rocks, which is equivalent to the composition of the "granite minimum" in the system Ab-Or-Q-H_2O. These rocks are of magmatic origin and may represent both metamorphosed rhyolites and products of melting of older granites.

Metamorphism

Sillimanite is present in aluminous schists occurring within the Hopyard, Pequot Swamp, Putnam, and Middletown formations throughout the entire area. Thus the rocks are entirely within the sillimanite zone of metamorphism (upper amphibolite facies). The metamorphic grade increases from north to south as indicated by changes in mineral assemblage in stratigraphic units lying along the Chester syncline. The most striking changes are shown by the Cremation Hill schist member of the Pequot Swamp fm., which can be followed continuously from the Middle Haddam quadrangle southward to Long Island Sound and around the south side of the Selden Neck dome. In most of the Deep River quadrangle (e.g. STOP 4) this schist is a binary schist, which locally contains sillimanite and generally contains pegmatitic Q-Pl-Ms laminae. In the Essex and Hamburg quadrangles the same unit contains no muscovite but does contain orthoclase and sillimanite and abundant pegmatitic Q-Pl-Or-Gt-Sill laminae (STOP 7). These changes are summarized in the following table. Other units show comparable, though less obvious changes from north to south.

Modal analyses of sections of
Cremation Hill schist

	Q	Pl	Bi	Ms	Sill	Or	Gt	Acc	Metamorphic facies
DR-78-5	37.4	9.8	36.5	11.5	tr	-	2.8	tr	"Sillimanite-muscovite" subfacies of the amphibolite facies
DR-44-5	31.2	19.3	29.4	18.5	tr	-	1.1	tr	
E-111-6	37.3	23.9	24.4	-	4.0	6.1	4.0	tr	"Sillimanite-orthoclase" subfacies of the amphibolite facies

These changes can be explained as products of progressive metamorphism effected by progressive dehydration and decarbonation of sedimentary rocks lying along the Chester syncline. The changes in the Cremation Hill schist, for example, may be related to the dehydration of muscovite in an initially muscovitic schist resulting in the development of a somewhat "drier" schist containing orthoclase and sillimanite. The following reaction probably is a crude expression of what really happened.

$$KAl_2AlSi_3O_{10}(OH)_2 + SiO_2 = KAlSi_3O_8 + Al_2SiO_5 + H_2O$$

	muscovite	+ quartz	= orthoclase	+ sillimanite	+ water
mol volume	142 cc	22 cc	105 cc	44 cc	

The interpretation favored is that the rocks in the southern half of the area were raised to a temperature (ca. 600° C) high enough that the Ms + Q reaction occurred, with the resultant replacement of every 10 percent muscovite initially present by about 6 percent orthoclase and 4 percent sillimanite. Biotite also seems to have been involved in dehydration reactions of a similar though more complicated nature. The temperature increase required resulted primarily from the upward displacement of isotherms around rising masses of once deeply buried hotter dome rocks. The narrow belt of tightly folded rocks lying along the Chester syncline was thus pinched between large volumes of somewhat hotter rock and also was continuously deformed, thus facilitating the escape of the large volume of water released by the dehydration of muscovite.

One corollary of this hypothesis is that the pegmatitic laminae in many high-grade schists are a product of metamorphism and simply represent a product of reorganization of material already present. Many geologists have favored the diametrically opposite hypothesis that the metamorphism is a product of the intrusion of pegmatite to form a lit-par-lit gneiss or schist.

Structural evolution

The structural problems present in the Deep River area are those common to gneiss-dome terrains throughout the world. Folds similar to the Chester syncline are common; they typically have highly sinuous axes and an axial "plane" that is actually a convoluted surface. The way in which such folds evolve, and thus, the relationship between such folds and the development of the domes is a structural problem of some interest. Of added interest in the Deep River area is the relationship between the Honey Hill fault and the other major structures.

The formation of the domes is here interpreted as a result of vertical upward movement, in the well known salt-dome style, of masses of rock having relatively low density and high plasticity. The rocks in the domes reached their present positions primarily as a result of plastic flow effected by recrystallization in the solid state, although relatively minor amounts of silicate melt may have facilitated the rise of the granitic domes in the areas of highest metamorphic grade. Such a mechanism was proposed by Eskola (1949) and has since been adduced by Thompson and Rosenfeld (1951), Walton (1955) and others as an explanation of similar relationships in other areas. The widespread occurrence of boudinage in amphibolite layers in the dome sequence is an indication of plastic flow in the gneisses; the size, shape, and extent of separation of individual boudins provides some measure of the minimum amount of flow in the gneisses.

The configuration of the mantle or synclinal sequence may be simply explained as consequence of vertical movement of the domes concomitant with movement along the Honey Hill fault. The mantling rocks were literally pinched between the rising cores of the domes, and folded isoclinal folds such as the Chester syncline were formed as a result of vertical movement of the dome rocks, with lateral compression being of secondary importance. The unsystematic extreme contortion of the rocks in the vicinity of STOP 8 (Connecticut Turnpike x Rt. 153) is presumably related to the differential rate and extent of upward movement of the domes. In this area, which lies at the center of a mass of rock surrounded by three (possibly four) gneiss domes, the synclinal sequence was tightly pinched and simultaneously twisted so that the syncline is here a twisted trough.

Other structural features of related interest are the V-shaped mass of Middletown formation northwest of Ivoryton and the remarkable little basin of Middletown around Vincent Pond, which appears (Fig. 3) as a feature with the configuration of a hole in a doughnut in the southeast sector of the Killingworth dome.

This part of the Killingworth dome was squeezed between the Clinton and Selden Neck domes; a pair of synclinal structures were thus superimposed on the gross structure of the dome.

The relationship between the rise of the gneiss domes and movement along the Honey Hill fault is an important problem. The field evidence, particularly in the structural knot around Chester (STOPS 1, 2, and 3) seemingly requires that the initial movement along the Honey Hill fault was contemporaneous, or nearly so, with the doming and metamorphism. The mantle was thrust southward over the dome sequence, the knot around Chester serving as the hinge point. Movement along the Honey Hill fault undoubtedly continued after the peak of metamorphism as indicated by the presence of mylonitic rocks containing mineral assemblages of somewhat lower grade than the rock from which the mylonite formed. One speculation that is being considered is that the rocks along the fault were being mylonitized at the same time as more deeply buried rocks to the south were being continuously folded and metamorphosed. In other words, it is possible that the entire structural and metamorphic evolution of the Deep River area took place more or less continuously during a long period of deformation centered around the time 260 million years B.P.

REFERENCES

Baird, D.M., 1951, The geology of the Burlington Peninsula, Newfoundland: Geol. Survey Canada Paper 51-21.

Billings, M.P., 1937, Regional metamorphism of the Littleton-Moosilauke area, New Hampshire: Geol. Soc. America Bull., v. 48, p. 463-566.

______________, 1956, The geology of New Hampshire, Pt. II, Bedrock geology: New Hampshire State Planning and Development Commission, Concord, N.H.

Eskola, P.E.; 1949, The problem of mantled gneiss domes: Geol. Soc. London Quart. Jour., v. 104, p. 461-476.

Hadley, J.B., 1949, Bedrock geology of the Mt. Grace quadrangle, Massachusetts: U.S. Geol. Survey Quadrangle Map Series.

Lundgren, L.W., 1957, The geology of the Deep River area, Connecticut: Ph. D. thesis, Yale University.

Lundgren, L.W., Snyder, G.L., and Goldsmith, Richard, 1958, A major thrust fault in southeastern Connecticut: Geol. Soc. America Program Abstracts for Annual Meeting, St. Louis (in press).

Mikami, H.M., and Digman, R.E., 1957, The bedrock geology of the Guilford 15-minute quadrangle and a portion of the New Haven quadrangle: Conn. Geol. and Nat. History Survey, Bull. 86.

Rodgers, John, 1952, Absolute ages of radioactive minerals from the Appalachian region: Am. Jour. Sci., v. 250, p. 411-427.

Taliaferro, N.L., 1943, Franciscan-Knoxville problem: Am. Assoc. Petroleum Geol. Bull., v. 27, p. 109-219.

Thompson, J.B., Jr., and Rosenfeld, J.L., 1951, Tectonics of a mantled gneiss dome in southeastern Vermont (abst): Geol. Soc. America Bull., v. 62, p. 1484.

Walton, M.S., 1955, The emplacement of granite: Am. Jour. Sci., v. 253, p. 1-18.

ITINERARY FOR TRIP D

50th Meeting - New England Intercollegiate Geological Conference
Trip Leader - Larry Lundgren
October 12, 1958

STOP 1: (a) Gillette Castle State Park - main parking lot. Typical exposure of interbedded biotite-quartz schist and calc-silicate granofels of the Hebron formation.

(b) Gillette Castle State Park - north of Castle on the east bank of the Connecticut River. Recumbent isoclinal fold in calc-silicate beds surrounded by biotite-quartz schist. Fold is within the Honey Hill fault zone and may have formed during the initial stages of thrusting. Slightly cataclastic calc-silicate beds are well exposed along cliff walk immediately below.

Proceed to Park entrance; turn right and continue to the east landing of the Chester Ferry. Turn right onto dirt road at the ferry landing to enter the grounds of Gillette Castle State Park along the east shore of the Connecticut.

STOP 2: (a) Cliffs immediately below the Castle. Cliff exposures of laminar mylonitic Hebron. Laminar structure offset along ultramylonite-filled shears indicating a late stage of movement in the reverse sense from that of the inferred direction of major movement.

(b) Small quarry immediately south of ferry landing. Cataclastic and mylonitic augen gneisses in contact with mylonitic Hebron. Three-dimensional exposure of layer of rotated pegmatite boudins in cataclastic gneiss, which lies immediately above the Honey Hill fault.

Return to cars and board the ferry. (If you back out of the dirt road you will be facing west and thus can board the ferry with a minimum of maneuvering.) Cross the Connecticut on the ferry (25 cents for car and driver, 5 cents for each passenger), and proceed southwest on Ferry Road across Rt. 9 and along Rt. 148. Turn right 0.25 miles west of Rt. 9 and proceed to point immediately north of Hearse Hill Cemetery.

STOP 3: Southwest end of Story Hill. Minor fold in porphyroclastic augen gneiss immediately above the Honey Hill fault. The sense of movement indicated by this fold is the same as that indicated by every minor fold in this structural knot (see Fig.2), and these folds apparently are reliable guides to the major structure. The overlying Hebron formation behaves in the same way on a large scale, and it is at this point that it is abruptly pinched into the Chester syncline.

(3a) Slightly cataclastic gneisses with an extraordinarily well developed banding are well displayed in a series of quarries along the east limb of the Chester syncline. One of these quarries will be visited if time permits.

Return to cars and proceed to the village of Chester. Turn west along Rt. 148 and proceed as far as Bochim Hill Road. Turn south along Bochim Hill Road to a point on the road just west of hill 240 (Deep River quadrangle).

STOP 4: Corner of Cockaponset State Forest. Condensed section across the Pequot Swamp formation on the west limb of the Chester syncline. Here the characteristic association of basal Di-Hbld amphibolite, garnetiferous biotite-quartz schist and gneiss, and binary schist is displayed. The binary schist is the Cremation Hill schist member, which locally contains sillimanite in association with muscovite. This assemblage (Bi-Ms-Q-Pl-Gt-(Sill)) is typical of this unit below the second-sillimanite isograd. Higher-grade equivalents of these units will be seen later.

Return to cars and proceed southeastward to Rt. 9, and follow Rt. 9 south to Kelsey Hill Rd. (Essex quadrangle). Turn right (west) onto Kelsey Hill Road. Rt. 9 runs along the east side of the keel of Hebron formation lying along the axis of the Chester syncline. Kelsey Hill Road takes you across this syncline just south of the second-sillimanite isograd, which lies along the boundary between the Deep River and Essex quadrangles. Proceed westward along Kelsey Hill Rd. for 0.5 mile.

STOP 5: North side of Kelsey Hill Rd. Discordant pegmatite cutting well bedded Hebron calc-silicate granofels. Pegmatites are particularly abundant along the narrow belt of Hebron lying along the axis of the Chester syncline, but they generally appear as concordant lenses.

Proceed westward on Kelsey Hill Rd. to the Valley Regional High School for lunch. Milk and ice cream available here but nothing else. After lunch proceed west on Kelsey Hill Rd. to Rt. 80. Turn right (north) on Rt. 80; follow 80 west to small roadside picnic area on north side of Rt. 80 adjacent to the Deep River town dump.

STOP 6: Short stop to be made if time permits. Extremely coarse anthophyllite rock in banded Pl-Q-Bi gneiss of the Middletown fm.

Proceed west to Stevenstown Rd. (Rt. 145) at the west edge of the Essex quad. and proceed south along 145 to the interchange over the Connecticut Turnpike.

STOP 7: Connecticut Turnpike exit to Rt. 145. The cuts in the exits and entrances and along the Turnpike itself display the association of amphibolite, biotite-quartz schist, and sillimanitic schist characteristic of the Pequot Swamp formation. Pale-pink spessartite-quartz-cummingtonite granulite is well exposed here also. These rocks are the stratigraphic equivalent of the rocks seen at STOP 4, but are at a higher metamorphic grade. Here Orthoclase and Sillimanite are common and may be regarded as the high-grade equivalent of muscovite (+ quartz). Part of the abundant pegmatite is regarded as a product of the dehydration of muscovite.

Proceed eastward along the Connecticut Turnpike to the next exit east. Cuts along the turnpike exhibit highly contorted amphibolite and gneiss along the axis of the Chester syncline. Exit onto Rt. 153, and park in the parking area at this exit.

STOP 8: Roadcut and natural outcrops in well banded amphibolite in which extensive boudinage has occurred. Three-dimensional exposure of one boudin. Please do not damage. Note pegmatite filling in the neck area of the boudins.